REMARKS

Claims 1-9 and 11-13 were rejected pursuant to 35 U.S.C. §112, first paragraph. The Examiner alleges that: the look-up table conversion from 2D display format to a 2D acquisition format is not shown since the acquisition format is a 3D data volume, and the 2D acquisition format with avoiding scan conversion of volume data not contributing to a final volume image is self contradictory.

Claim 1 has been amended to remove the "two-dimensional" acquisition format. Claim 1 and the corresponding dependent claims 2-9 and 11-13 are supported by the original disclosure.

Claims 14-20 and 22-27 were rejected pursuant to 34 U.S.C. §101 as being directed to non-statutory subject matter. Both claims 14 and 22 are directed to statutory subject matter. The transformation of data representing a patient into an image is directed to statutory subject matter (See In re Bilski).

In response, the Examiner alleges the claim is directed to change in format of data that has already been collected, so is not statutory. The Examiner notes that the steps of identification and interpolation are not tied to a machine.

Independent claims 14 and 23 have been amended to require that the look-up table is in a memory and a processor performs the interpolating. These method claims are tied to a statutory class, so are directed to statutory subject matter.

In the Office Action, the Examiner again rejected claims 1, 3, 5, 11-14, 16, 18, and 24-26 pursuant to 35 U.S.C. §103(a) as unpatentable over Halmann, et al. (US 6,526,163) in view of Seiler, et al. (EP 1,093,085). Claim 2 was rejected pursuant to 35 U.S.C. §103(a) as unpatentable over Halmann, et al. in view of Seiler and further in view of Zar (A Scan Conversion Engine...). Claims 4 and 17 were rejected pursuant to 35 U.S.C. §103(a) as unpatentable over Halmann, et al. in view of Seiler, et al and Hossack, et al. (US 6,352,511). Claims 6 and 19 were rejected pursuant to 35 U.S.C. §103(a) as unpatentable over Halmann, et al. in view of Seiler, et al. and Okerlund, et al. (US 6,690,371). Claims 7 and 20 were rejected pursuant to 35 U.S.C. §103(a) as unpatentable over Halmann, et al. in view of Seiler, et al. and Drebin, et al. (US 4,835,712). Claims 9 and 22 were rejected pursuant to 35 U.S.C. §103(a) as

unpatentable over Halmann, et al. in view of Seiler, et al. and Swerdloff (US 5,483,567). Claim 15 was rejected pursuant to 35 U.S.C. §103(a) as unpatentable over Halmann, et al. in view of Seiler, et al. and Fattah (US 7,274,325). Claim 27 was rejected pursuant to 35 U.S.C. §103(a) as unpatentable over Halmann, et al. in view of Seiler, et al. and Edic, et al. (US 2004/0136490).

Claim 10 was allowed. Claim 21 was objected to as being allowable if amended into independent form.

Applicants respectfully request reconsideration of the rejections of claims 1-9, 11-20, and 22-27, including independent claims 1 and 14. *New remarks are provided below in italics.*

Independent claim 1 recites a processor operable to identify acquired ultrasound data as a function of the values where a look-up table has the values corresponding to a spatial conversion from the display format to the acquisition format.

Halmann, et al. do not disclose this limitation. Halmann, et al. note that a CPU generates the scan converter tables necessary to convert scanned data from the polar coordinate system to the Cartesian coordinate system where the tables are dependent on the mode of operation (col. 7, lines 54-59). Scan conversion is performed with interpolation and the like (col. 8, line 53-col. 9, line 4). Halmann, et al. do not provide further details for the tables, but indicate that the tables convert the data. Halmann, et al. do not use values of the table to identify ultrasound data. There is no teaching that acquired ultrasound data is identified as a function of the values of the look-up table.

The tables of Halmann, et al. would be used by applying each ultrasound datum to the table. The table then provides for conversion of the ultrasound data. Each datum is converted, so the identity of a given ultrasound datum is not needed. The original data is converted regardless of identity.

Claim 1 recites that the table has values corresponding to a spatial conversion from the display format to the acquisition format. Halmann, et al. convert polar coordinates into Cartesian coordinates (col. 7, lines 55-57; and col. 8, lines 64-65), not a look-up table used for the inverse conversion of Cartesian coordinates to the polar coordinates.

The Examiner alleges that, since the scan conversion is converting the polar scanned data to display values, it is identifying the polar data as a function of the Cartesian values,

and alleges that the look-up table is reversible. However, Halmann, et al. do not disclose the structure of the lookup table. The lookup table, to be used for scan conversion, likely has interpolation values (not a Cartesian coordinate) given an input Polar coordinate. The interpolation values are then applied to the data for that Polar coordinate to weight the data and create Cartesian data. The table is likely for interpolation values for the actual conversion of data at particular coordinates, so would not have a Cartesian coordinate output given a polar coordinate input.

Even if the table is addressed by scan coordinates, to use inversely, the specific interpolation values, not a Cartesian coordinate, would be needed to address the table. For example, the table would be addressed by polar coordinate to output interpolation weights (e.g., 0.93). These interpolation values correspond to spatial relationships, so may be identical for different locations. Using the table in reverse would result in multiple polar coordinates given an input interpolation value.

Even if reversible, Halmann, et al. convert polar coordinate data to Cartesian coordinate data. There is no reason to identify polar coordinate data from or starting with a Cartesian coordinate. The process flows by providing polar coordinate data. The polar coordinate data is then interpolated (weighted and summed) to represent data at a Cartesian coordinate. The location of the Cartesian coordinate does not need to be known before hand. The available polar coordinate data is converted. An inverse lookup would not occur.

The Examiner points out that Halmann, et al. disclose interpolation with respect to the lookup table. Applicants agree. However, the tables are created to "convert scanned data from the polar coordinate system to the Cartesian coordinate system" (col. 7, lines 54-57). This is done for converting incoming data from the polar coordinate system to the Cartesian coordinate system (col. 6, lines 10-12). It is hindsight, in light of this specific teaching to convert from polar to Cartesia, or, to suggest conversion from Cartesian to polar. Halmann, et al. do not suggest reverse lookup. The system is not configured for reverse lookup.

Independent claim 1 further recites that the processor is operable to avoid scan-conversion of volume data that does not contribute to a final volume rendered image, the identifying corresponding to identifying for display format coordinates associated with

visible voxels of the final volume rendered image. Halmann, et al. and Seiler, et al. do not disclose these limitations.

Halmann, et al. simply scan converts all the incoming polar coordinate values for imaging. All the scan conversion tasks are completed so that a 2D image is generated (col. 9, lines 4-13). Volume rendering is performed from the 2D images (col. 5, lines 34-40). Halmann, et al. rely on polar coordinate to Cartesian coordinate scan conversion, converting all of the frames of data to provide 2D images, and then perform volume rendering from the 2D images. Halmann, et al. do not operate scan conversion as a function of the volume rendering, so do not avoid scan-conversion of volume data that does not contribute to a final volume rendered image, the identifying corresponding to identifying for display format coordinates associated with visible voxels of the final volume rendered image.

The Examiner takes a mere general statement about generating scan conversion tables and alleges obviousness of the claim, indicating hindsight reasoning.

Seiler, et al. also do not avoid scan conversion. As known in the art and recited in the claim, scan conversion corresponds to a spatial conversion from an acquisition format to a two-dimension display format. Seiler, et al. do not disclose scan conversion. Instead, a volume of data is the starting point (paragraphs 2, 8, and 34-35). Volume sections are reviewed to avoid transfer for 3D rendering of 3D voxels. Seiler, et al. start with volume data and avoid 3D rendering of voxels, so do not avoid scan conversion.

The Examiner notes that the concept of skipping unviewable sections of a volume is applicable to both ray tracing and scan conversion, so a person of ordinary skill in the art would apply it to scan conversion. However, neither Seiler, et al. nor Halmann, et al. connect this concept of avoiding scan conversion with reverse lookup. Halmann, et al. do not disclose reverse lookup (i.e., conversion of display coordinates to acquisition coordinates). Seiler, et al. use visibility tests as part of ray casting (paragraphs 29 and 30). Seiler, et al. test cut-planes (paragraph 55), cropping boundaries (paragraph 55), depth test (paragraph 56), early ray termination (paragraph 61), and space leaping (paragraph 66) to identify voxels that do not need to be loaded. Seiler, et al. do not determine visibility by identifying acquisition data from display coordinates. The two references scan convert and

then render with the converted volumes. Seiler, et al. test visibility on the volume data. The two references do not disclose a processor configured to avoid scan-conversion of volume data that does not contribute to a final volume rendered image, the identifying corresponding to identifying for display format coordinates associated with ***visible voxels*** *of the final volume rendered image.*

A person of ordinary skill in the art would not have used the avoidance of transfer of voxels with the scan conversion of Halmann, et al. Seiler, et al. use as input a volume set of data. Halmann, et al. generates 2D images by scan conversion (col. 9, lines 4-13). A collection of the scan converted images are used to form a volume data set for rendering. (col. 5, lines 33-40). Halmann, et al. treat scan conversion and rendering separately. A person of ordinary skill in the art would have used the voxel control for rendering of Seiler, et al. with the rendering of Halmann, et al., not the different scan conversion process.

A person of ordinary skill in the art would not have used the voxel transfer avoidance of Seiler, et al. with the scan conversion of Halmann, et al. for another reason – failure to enable. Seiler, et al. rely on the data in a volume arrangement or volume sections extracted from the volume data to determine which voxels not to use. The view direction, size of the volume, equations for cut and crop planes in the volume, and bounding boxes are volume related factors used to select voxels (paragraphs 77 and 78). The volume data set is needed to even determine these factors. As of the scan conversion of Halmann, et al., the volume data set is not yet created. A person of ordinary skill in the art would not know how to use voxel selection in the scan conversion process since Seiler, et al. provide a process for a rendering pipeline with the volume data as a starting point.

The Examiner alleges that the combined teachings would improve efficiency by bringing the extra rendering avoidance techniques of Seiler, et al. in to Halmann, et al. First, the techniques of Seiler, et al. do not involve identifying acquisition data by conversion from display coordinates associated with visible voxels. Seiler, et al. identify voxels that are or are not visible regardless of the display coordinates. Second, porting just the concept of avoidance to Halmann, et al. does not provide a way for implementing this in Halmann, et al. except in the post scan conversion rendering of Halmann, et al. Halmann, et al. scan convert

all, and then use the scan converted data as a volume for rendering. Seiler, et al. teach visibility testing in rendering. If combined, the rendering teaching of Seiler, et al. would be used in the rendering of Halmann, et al. The rendering of Halmann, et al. is independent of and occurs after the scan conversion.

Using 3D rendering voxel transfer avoidance of Seiler, et al. in the scan conversion of Halmann, et al. is using improper hindsight reasoning.

The inventor, Gianluca Paladini (inventor of 10 patents), drafted his own remarks provided in this and the following paragraphs in italics. In Halmann et al. (US 6,526,163), there is a clear separation between a scan conversion module 207 and a volume rendering / ray casting module 201. Halmann teaches that a "scan converter module 207 converts incoming data from the Polar coordinate system to the Cartesian coordinate system. The ***foregoing*** *modules 201-208 may divide the operations associated with each module into tasks..." (column 6, lines 10-14). Such sentence indicates that "foregoing" module 201 is used after module 207.*

Halmann describes a "volume rendering / raycasting module 201 constructs a 3-dimensional volume from a series of 2-dimensional images. The module 201 ***then*** *performs known volume rendering and/or raycasting techniques to produce an image for display" (column 5, lines 34-38)(emphasis added). Such sentence indicates that an entire 3-dimensional volume is constructed before rendering, and "then" rendering takes place.*

Current claim 1 describes a very different approach, whereby scan-conversion takes places during volume rendering (not before as in Halmann et al.) as a function of the values being interpolated, and that scan conversion of volume data that does not contribute to a final volume rendered image is avoided. This approach is much more efficient than the one suggested by Halmann's et al., due to avoiding scan-conversion of the entire volume data before rendering the volume. Halmann does not teach that the process of volume rendering can be used to selectively determine what is visible in order to avoid unnecessary scan-conversion computations.

In Halmann's claims 1-3, it is evident that scan conversion is its own separate process, where Halmann suggests scan conversion can be divided into parallel scan

conversion tasks. His solution to the problem of having to scan convert all the volume data suggests the use of parallel processing tasks distributed onto multiple CPUs, while the solution of current claim 1 is to avoid unnecessary scan-conversion computations in the first place. Note also that in Halmann's method, scan conversion is separate from rendering and display and therefore scan conversion is implicitly view-independent. The solution of current claims 1 is implicitly view-dependent as illustrated in Figure 5a of our application. Since only the visible samples contributing to a given view of the volume are scan-converted in claim 1, different samples are scan converted every time the arbitrary observer location 501 changes. Halmann's method would not provide for such change.

Seiler describes known methods for skipping over voxels or samples that are explicitly clipped ("pruning"), obscured by other parts of the volume ("early ray termination"), or transparent parts of the volume ("empty space skipping"). These concepts are not his original ideas, as they have been known in the art of volume rendering and described in a back as early as 1990. What Seiler is suggesting is that such methods are easy to implement in software but are very difficult to implement in hardware. The method he describes in EP 1,093,085 therefore focuses on a particular hardware apparatus for volume rendering. As evident in Seiler's claim 1, 5 and 6, the volume data already exists and it is partitioned into various sections and blocks for visibility tests. Therefore, Seiler's apparatus is relying on volume data that already exists in the form of a three-dimensional volume containing voxels <u>before</u> rendering can take place. In the system of current claim 1, the three dimensional volume does not exist yet, because the voxel values of the three dimensional Cartesian volume being rendered have not been scan-converted yet. Sample values are scan-converted on the fly selectively by converting Cartesian coordinates to Polar coordinates for each visible sample along a ray passing through a "virtual" Cartesian volume (see description [0091] and [0102] in our application), so that polar data values can be interpolated. This approach is very different from Seiler's, where samples are interpolated from existing Cartesian voxel values.

Note also that in Seiler's method, since voxel values are assumed to already exist before rendering, such method is implicitly view-independent. The solution of claim 1 is

implicitly view-dependent as illustrated in Figure 5a of our application. Since only the visible samples contributing to one view of the volume are scan-converted, different samples are scan converted every time the arbitrary observer location 501 changes.

To summarize:

1) Claim 1 is implicitly view-dependent, because samples are scan converted based on a particular observer position associated with the volume rendered image; the prior art scan converts first and THEN renders, therefore they do not need to scan convert again when the observer position changes; however they have to scan convert ALL data, while claim 1 scan converts data selectively and in an inverse way (cartesian to polar). Each approach has its PROs and CONs: their method takes longer to perform scan conversion because they have to scan convert all data, but then it perform faster at rendering time because they do not have to scan convert again if they are simply moving the orientation of the camera around the volume; our method saves processing time by not scan converting all polar data upfront, instead it selectively scan converts only visible samples for a particular position of the observing camera, however rendering performance is not as fast when the observer's position changes, as we have to selectively scan convert new samples again.

2) The prior art scan converts data from polar to cartesian - which involves a first interpolation step possibly using a look-up table, and then renders an ACTUAL cartesian volume - which involves a SECOND interpolation step using cartesian voxel data. The system of claim 1 has a "virtual" cartesian volume with no data in it, and a SINGLE interpolation step which is computed by converting cartesian coordinates to polar coordinates and interpolating polar data is provided.

Independent claim 14 is allowable for similar reasons as claim 1.

Dependent claims 2-7, 9, 11-13, 15-20, 22, and 24-27 depend from claims 1 and 14, and are allowable for the same reasons as the corresponding base claim. Further limitations patentably distinguish from the cited references.

Claim 2 recites that the values comprise Polar coordinates, the look-up table entries indexed by integer Cartesian coordinates and wherein the processor is operable to bilinearly interpolate from the look-up table values using fractional offsets of Cartesian coordinates.

As noted by the inventor, Halmann states that a "scan converter module 207 converts incoming data ***from the Polar coordinate system to the Cartesian coordinate system*** *" (column 6, lines 10-12)(emphasis added). Base claim 1 provides that samples passing through a "****virtual****" Cartesian volume are scan-converted by converting* <u>*Cartesian coordinates to Polar coordinates*</u>*, thereby the interpolation takes place in the Polar coordinate system – the opposite of what Halmann and Zar disclose. Claim 2 depends on Claim 1, where we have shown that Seiler does not teach the concept of a virtual Cartesian volume – instead he assumes that Cartesian voxel data already exists.*

Claims 3 and 16 recite determining the display coordinates of interest and identifying the acquired ultrasound data by input of the display coordinates into the look-up table. The Examiner cites to col. 8, lines 4-9 of Halmann, et al. Halmann, et al. may locate an area of interest, but the area is not used to identify acquired data by input into the look-up table. Identifying all ultrasound data is not using the area to identify data.

The Examiner alleges that all the data is the area of interest. However, Halmann, et al. do not provide a process for less than all data being the area of interest. Accordingly, Halmann, et al. do not provide for identifying acquired data by input of determined display coordinates.

Claims 5 and 18 recite the display coordinates of interest input to the look-up table being coordinates for a plurality of rays through the volume. Halmann, et al. disclose a raycasting/volume rendering module 201, but this module 201 is not shown to work with the tables of the separate scan conversion module 207. The Examiner alleges there is no way to render an image if the original coordinates are polar, but that is not true. The rendering can account for any coordinate system. The rendering, rather than scan conversion, may provide data for each pixel based on ray casting, regardless of the format of the input data. Halmann, et al. do not put ray coordinates into a scan conversion look-up table.

The Examiner notes that Halmann, et al. disclose lookup tables for scan conversion, so one skilled in the art would use tables with raycasting. However, Halmann, et al. treat rendering and scan conversion separately. Rendering, unlike scan conversion, is not disclosed as using tables. Instead, raycasting is used with interpolation along the rays. The

interpolation to the rays and then blending provides the pixel values.

Claim 26 recites generating a two-dimensional look-up table with acquisition format coordinates for each coordinate of a Cartesian volume. Halmann, et al. treat volume rendering separately from scan conversion. There is no disclosure of a LUT for coordinates of a Cartesian volume. The Examiner alleges there is no way to render an image if the original coordinates are polar, but that is not true. The rendering can account for any coordinate system. Also, the process of Halmann, et al. may be used – convert from Polar to Cartesian. The image is rendered from a volume of Cartesian data, so a reverse table would not be used.

Halmann, et al. treat rendering and scan conversion separately. Rendering, unlike scan conversion, is not disclosed as using tables. Instead, raycasting is used with interpolation along the rays. The interpolation to the rays and then blending provides the pixel values.

Claim 4 recites the processor operable to determine a plane through a volume as the display coordinates where the display coordinates are input to the look-up table. Hossack, et al. show arbitrary plane display for a volume, but do not use the coordinates of the plane as an input to the look-up table. Halmann, et al. treat volume rendering and scan conversion separately, so do not use coordinates of a plane in a volume as input to the scan conversion table. The form of conversion used would be the form taught by Halmann, et al., not a reverse conversion that also intermixes the separate rendering process. Claim 17 is allowable for similar reasons.

The Examiner points out that some sort of conversion must be done to obtain display data and Halmann, et al. use the LUT for conversion. However, rendering a plane from a volume is not handled as scan conversion by Halmann, et al. In rendering, the display values are interpolated from the already scan converted volume. Hossack, et al. shows scan conversion of 2D planes, such as performed by Halmann, et al. Halmann, et al. then perform rendering from the collected planes. A LUT is not disclosed as being used for rendering. The data is already in a Cartesian format.

As noted by the inventor, by association with Claim 1, claims 4 and 17 imply that the

cross-section is also computed by selective scan-conversion of only the samples required to form the image plane, as illustrated in Figure 5b of the application. Hossack describes a scan converter 34, stating "the scan converter comprises a device for reformatting polar coordinate ultrasound data into Cartesian coordinate ultrasound data" (column 5, lines 62-65), which is described as a separate module from the subsequent display step 36. Hossack does not teach a combined display and scan-conversion process where scan-conversion selectively skips samples which do not contribute to the final image. Hossack also does not teach the use of a "virtual" Cartesian volume which does not contain any voxel data – in fact, claims in Hossack focus solely on a method for persistence of ultrasound data, the opposite of our approach where no Cartesian volume data is ever persisted, and new samples are always scan-converted on the fly based on a particular observer location.

Claims 6 and 19 are allowable for the same reasons as claim 5. *Claims 6 and 19 are also allowable because Okerlund, et al., like Halmann, et al. and Seiler, et al., do not treat rendering and scan conversion together. A collection of images or display formatted data is used to form the volume (col. 3, lines 47-60).*

As noted by the inventor, by association with the base claims, claim 6 and 19 selectively avoid scan-conversion of volume data that does not contribute to a final volume rendered image. In 6,690,371, Okerlund describes a typical setup of a medical imaging workstation with a rendering component 86 which can visualize acquired medical data. Commercial systems as such have been available decades before Okerlund's filing date of May 3, 2000 and his description of the rendering component does not teach anything new other than one very particular idea, which was incorporated in the claims, where the visualization comprises the rapid production of a "reduced-fidelity" image by using a "decimated image volume" which gets refined to a full-fidelity image in subsequent steps. Okerlund does not teach the idea of sampling a "virtual" Cartesian volume and selectively scan-convert only the samples that contribute to the final image through inverse look-up. In addition, the recited system does not rely on decimated "reduce-fidelity" data – in fact, the claimed approach produces results that are superior even to the "full-fidelity" images described by Okerlund, and superior to images which would be produced by Halmann and

Seiler. By scan-converting data prior to rendering, Halmann relies on existing voxel values in a Cartesian dataset, and therefore during rendering his method interpolates Cartesian voxel values. Such values have already undergone a previous interpolation step from Polar to Cartesian in the scan converter module, therefore Halmann's approach interpolates two times and as a result the image quality is blurrier. Seiler perform the same multiple interpolation. In the recited approach of claims 6 and 19, the "virtual" Cartesian volume does not contain any data, and each sample is interpolated on the fly only once from Polar data – we therefore have one less interpolation step, and the image quality is improved compared to systems relying on Halmann, Okerlund, and Seiler.

By association with claims 1 and 14, claims 9 and 22 selectively avoid scan-conversion of volume data not contributing to the final image. Swerdloff does not teach a method for selective scan conversion of volume data. Swerdloff teaches a method for converting Polar data in a tomographic reference frame to Cartesian data ("Polar to Cartesian Conversion" section in Swerdloff patent), the opposite transform as the one used in our application. The method converts <u>all</u> Polar data and does not selectively discard data that does not contribute to the final image: this is illustrated in Fig. 3, step 50 ("for each polar voxel") which is the outer loop controlling the entire conversion process. In addition, due to the fact that Polar data is being converted to Cartesian with a method known in the art as "forward mapping", Swerdloff's method has no choice but to truncate Polar volume elements against the overlapping Cartesian volume elements and sum the resulting areas of truncated volume elements with appropriate weight values. Our method relies on "inverse mapping" from Cartesian to Polar, therefore we do not require to compute such truncated overlapping areas.

Claim 12 recites a flag, and an integer sum. As noted in the specification, an integer sum allows indication of spatial relationship relative to other table entries. Halmann, et al. do not suggest any format for the look-up table, and certainly do not disclose an integer sum, a flag or fixed-point values. These values are chosen to allow table based identification of data rather than scan conversion of the data. Selective scan conversion of only the samples that contribute to the rendering result without having to scan convert occluded data is

provided by the recited table variables. A person of ordinary skill in the art would not have provided the listed classes as a mere design choice. The flag and integer sum would not have been considered as there is no reason for them in Halmann, et al. Just being well known is insufficient.

The Examiner notes that there is no reason to use a flag and integer sum in Halmann, et al. and alleges the same for the invention, so that they are a design choice. The Examiner then alleges that the claimed invention does not recite indication of a spatial relationship and that other variables may work. However, the claimed invention is about scan conversion, which is a spatial relationship. The flag and integer sum efficiently track visibility for the claimed reverse lookup. Given the teachings of Halmann, et al., a person of ordinary skill in the art would not have used the flag and integer sum as a design choice.

<u>CONCLUSION</u>:

Applicants respectfully submit that all of the pending claims are in condition for allowance and seeks early allowance thereof.

PLEASE MAIL CORRESPONDENCE TO:

Siemens Corporation
Customer No. 28524
Attn: Elsa Keller, Legal Administrator
170 Wood Avenue South
Iselin, NJ 08830

Respectfully submitted,
/Rosa S. Kim/

Rosa S. Kim, Reg. No. 39,728
Attorney(s) for Applicant(s)
Telephone: 650-694-5330
Date: August 6, 2009